

MULTI-TOUCH

By

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FINAL REPORT

Submitted to the Electrical and Electronic Engineering Program
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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By

Mohamed Afif, 2010

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronic Engineering Program
Universiti Teknologi PETRONAS
In partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

(Mr. Patrick Sebastian)

Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
DECEMBER 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohamed Afif Bin Che Mohamed Rus

ABSTRACT

The current limitation of interaction with computer is using indirect devices such as mouse and keyboard. Results of interaction are displayed on the monitor. Meanwhile, the current operating systems are limited to one pointing device. The most obvious limitation of one pointing device is, it unable to compensate with multi input touch at one time. Hence, the form of interaction between human and computer become restricted at certain point. Following with the new complexity of application been developed in various sector, usage of multi input application become integral in recent application. With the introduction of multi-touch, a new form of human computer interaction is introduced. Multi-touch term refer to abilities of the touch screen to handle multiple input or gesture at one time. Without using a pen or stylus to interact, multi-touch can respond to the multiple finger movement. The main idea of this technology is to allow user to interact with computer in the natural way. With this idea evolve around this project, system respond become the most important core in order to maintain the ideality of this project. The main contribution in this project is first, by optimize the multi-touch simulation to demonstrate the multi input abilities and proceed with hardware implementation which will be in the second stage of this project, Final Year Project (FYP) II.

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LIST OF ABBREVIATIONS

IR	Infra Red
LED	Light Emitting Diode
LCD	Liquid Crystal Display
FTIR	Frustrated Total Internal Reflection
DI	Diffused Illumination
FDI	Front Diffused Illumination
RDI	Read Diffused Illumination
OpenCV	Open Source Computer Vision
CCV	Community Core Vision
TUIO	Tangible User Interface Protocol
FLOSC	Flash Open Sound Control

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Multi-touch can be derived from the touch screen technology. Multi-touch technology is not entirely new technology because it is established since 1970s with different forms. A touch screen is an electronic visual output that can detect the presence and location of a touch within the display area. The term generally refers to touch or contact to the display of the device by a finger or hand. [1] In a broader term, touch screen will act as input and output device. Multi-touch term refer to abilities of the touch screen to handle multiple input or gesture at one time. Without using a pen or stylus to interact, multi-touch can respond to the multiple finger movement. The movement of finger represents gesture. With specific gesture, we can program our multi-touch device on how to interact with the gesture. There is no standard software to implement multi-touch. Some systems are based on camera and capacitive technologies. Therefore, it leads to several design approaches based on the type of capabilities of the device. [1] With the introduction of multi-touch into real world, a new form of human interaction is introduced.

1.2 Problem Statement

Due to recent innovations and devices developed in the market, multi-touch technology becomes affordable. There are several ways to implement the multi-touch such as projecting the images to acrylic or plastic sheet and produce the backlight of the images from Infrared Light Emitting Diode (IR LED). The backlight of IR LED will present a blob. In this project, camera and based multi-touch technology will be constructed. Camera with IR filter will detect the blobs and send the blob coordinate to the software, hence, translate the blob into known gesture.

1.3 Objective and Scope of Study

The objectives of the project are:

- To recognize multi input and gesture
- To run simulation without hardware setup
- To build camera-based multi-touch table

The project divided into two parts, software and hardware. The simulation of multi-touch without hardware setup was implemented in Final Year Project I (Semester 7). Meanwhile, Final Year Project II (Semester 8) will be dedicated to build hardware setup which undergo several phase of assembly before proceed with the best technique which is Frustrated Total Internal Reflection (FTIR). Software implementation can be divided into three different parts. The first part is about the understanding of multi-touch device to receive touch or gesture as an input. The second part is about the understanding of software available to setup multi-touch device. Last but not least, the implementation of multi-touch simulation. Research on image processing and programming also need to be done intensively before proceed with hardware implementation. Open Source Computer Vision (OpenCV) [2] is used in this project for image processing purpose.

CHAPTER 2

LITERATURE REVIEW

2.1 Concept

This project can be divided into three parts:

- Human
- Software
- Hardware

General interaction for multi-touch can be described as shown by Figure 1. It begins when the user want to interact with the display. To initialize the interaction, the user touches the panel. This interaction was registered as input by the camera. However, the camera also registered the background when user touches the panel. Therefore, the background must be removed in order to allow only touches as the input. The captured image is converted into the grayscale image and the static background is removed by subtracting the current frame with the reference frame. As a result, only the contacts (blob) are passed through and register as input to the system. By using blob tracker system, this system was able to process blob coordinate in the display plane. The movement of blob in this system will trigger the multi-touch application and produce the desired result.

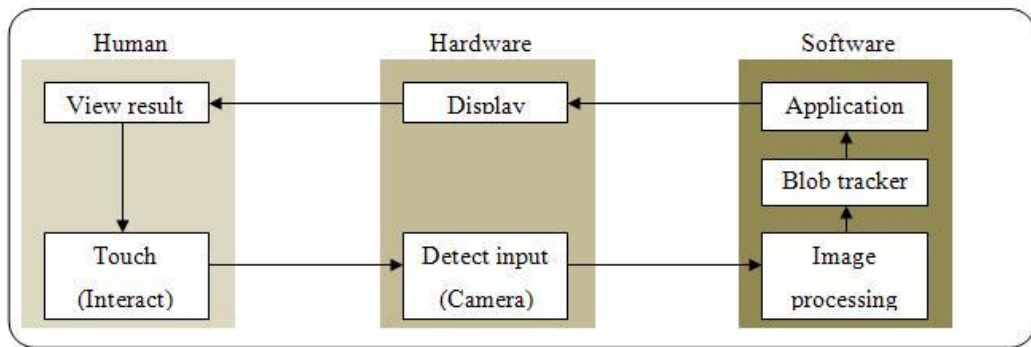


Figure 1 Overview of multi-touch interaction

2.2 Technique

Frustrated Total Internal Reflection (FTIR) and Diffused Illumination (DI) are the common techniques for the camera based multi-touch technology. These techniques consist of optical sensors (camera), IR LED and visual feedback in form of projector or LCD. IR LED is used mainly to distinguish between the visual image and the blob that been tracked in the system.

2.2.1 Frustrated Total Internal Reflection (FTIR)

This project based on FTIR which developed by Jeff Hann. Total Internal Reflection (TIR) describes a condition present in certain materials when light enters one material to another material with higher refractive index, at an angle of incidence greater than a specific angle. [3] If the refractive index is lower on the other side of the boundary, no light can pass through which effectively reflect the light. [4] TIR keeps trapped within the sheet, except at points where it is frustrated by some object (finger) in optical contact, causing the light to scatter out through the sheet towards the camera [5]. This project effectively uses this phenomenon. Figure 2 shows the setup of FTIR.

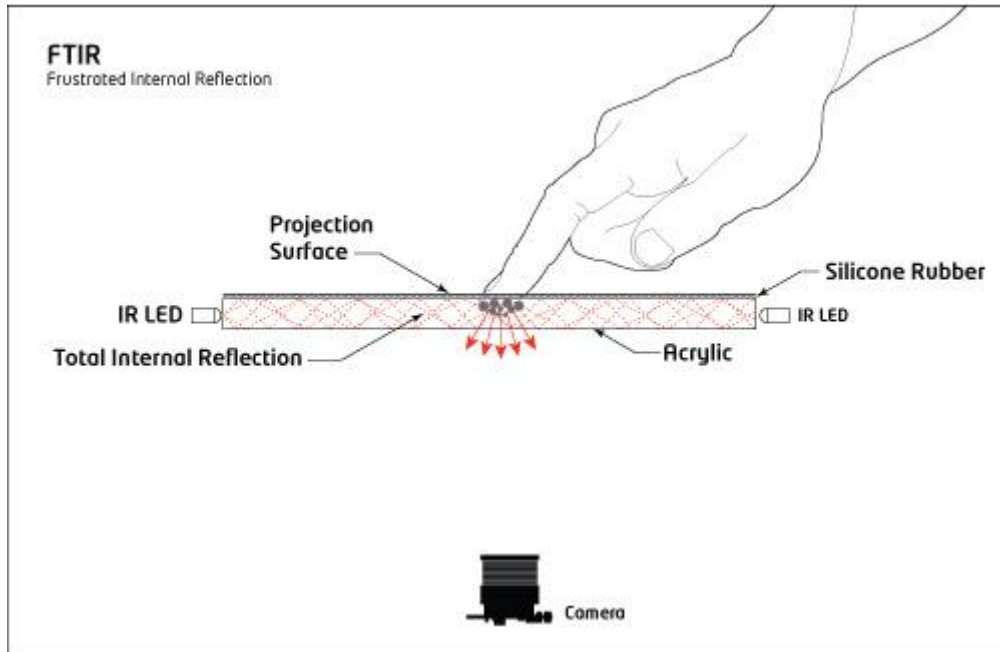


Figure 2 FTIR [6]

2.2.2 Diffused Illumination (DI)

Another technique that can be used for multi-touch is Diffused Illumination (DI). There are two types of DI which are Diffused Surface Illumination (DSI) and Rear DI (RDI).

2.2.2.1 Diffused Surface Illumination (DSI)

DSI is based on light being diffused. Instead of using IR LED, this technique use ambient light from the environment. A diffuser is place on top or bottom of the touch plane. By touching the touch plane, a shadow will appear underneath the fingertips because the ambient light cannot reach it. Then, the camera will detect the shadow as input. Figure 4 shows the DSI setup.

2.2.2.2 Rear Diffused Illumination (RDI)

IR is shine at the screen below the touch surface. When users interact with the surface, the surface will reflect the more light than the diffuser or object in the background. Camera will detect this extra light. Figure 3 shows the RDI setup.

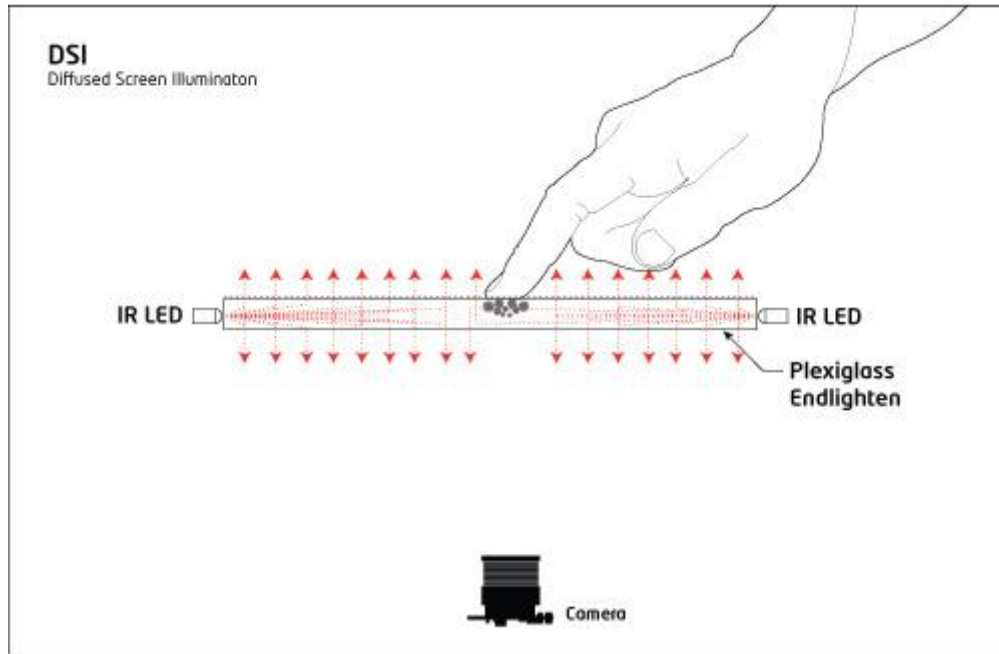


Figure 4 DSI [7]

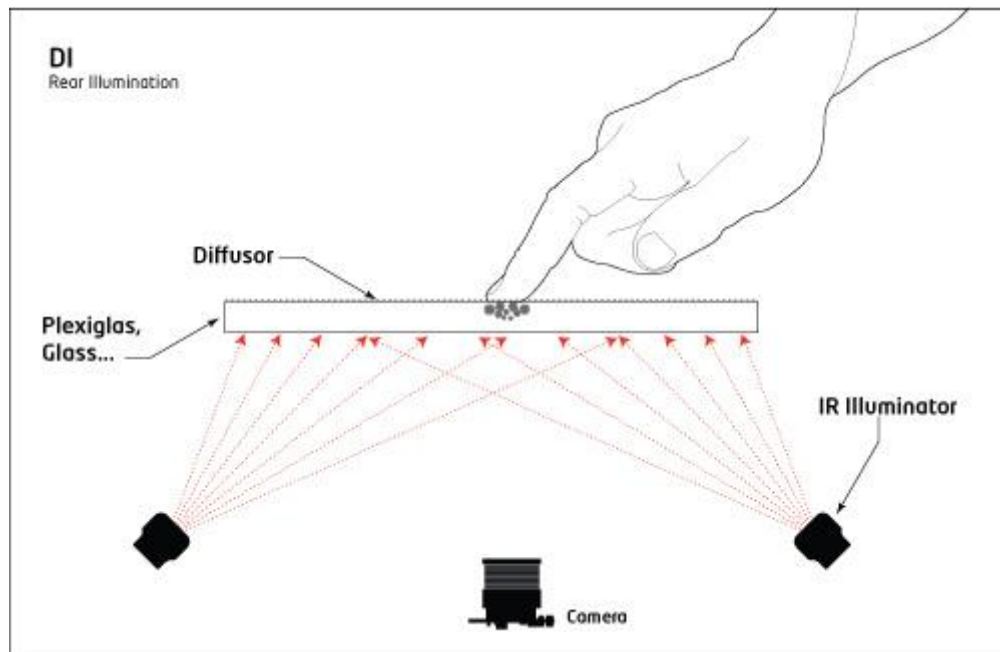


Figure 3 RDI [8]

2.3 Image Processing

Image processing (or blob tracking) are very important in multi-touch in order to receive an input without any external interference. Therefore, the software which handles image processing is crucial in detecting the input. reactTIVision and Computer Core Vision (CCV) are capable to do the image processing with high accuracy in detecting the input.

2.3.1 *reactTIVision*

reactTIVision is an open source, cross-platform computer vision framework for the fast and robust tracking of fiducial markers attached onto physical objects, as well as for multi-touch finger tracking. Figure 5 shows reactTIVision GUI. It was mainly designed as a toolkit for the rapid development of table-based tangible user interfaces (TUI) and multi-touch interactive surfaces [9].

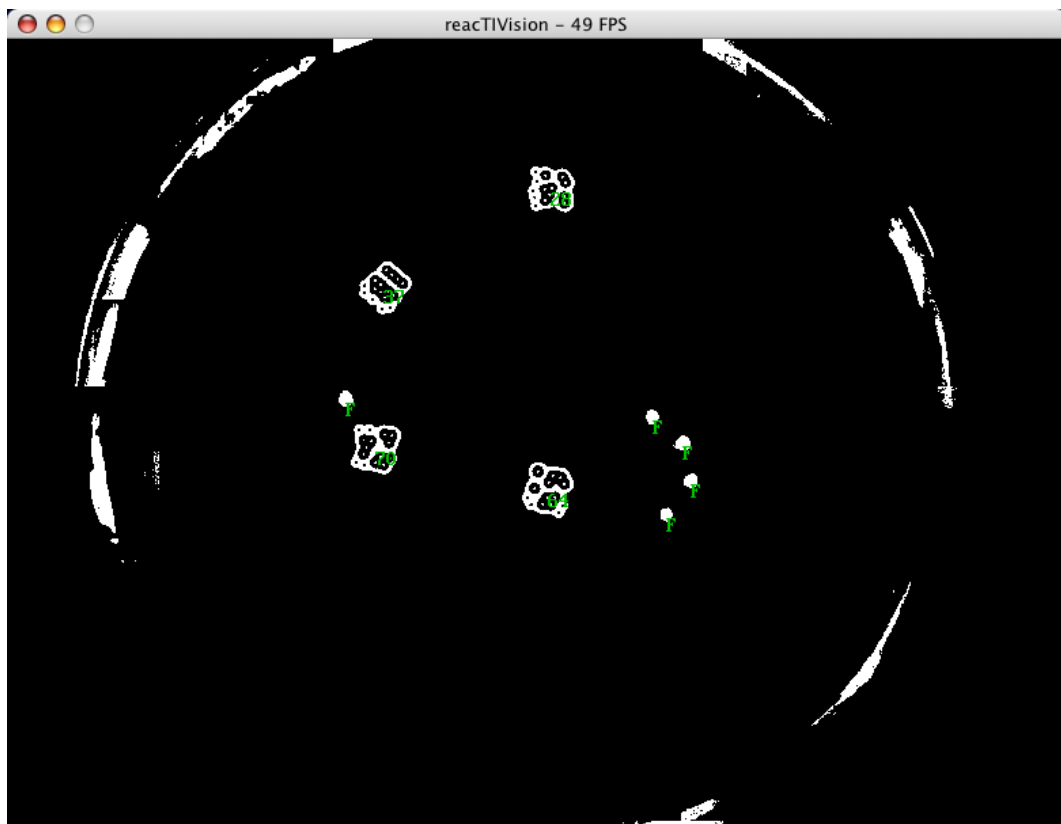


Figure 5 reactTIVision [9]

2.3.2 Community Core Vision (CCV)

Community Core Vision (CCV) is an open source/cross-platform solution for computer vision and machine sensing. CCV can interface with various web cameras and video devices as well as connect to various TUIO/OSC/XML enabled applications and supports many multi-touch lighting techniques including FTIR and DI.[10] CCV become the favorite for blob tracking because the code is open source. It takes a video input stream and outputs tracking data (e.g. coordinates and blob size) and events (e.g. finger down, moved and released).

2.4 TUIO Protocol

Multi-touch is a two-step process where reading and translated the blob input from the camera. After that, the blob will be channeled with the process data to the framework which raw blob data to be assembled to recognize gesture that high-level language use to interact with the application. Tangible User Interface Protocol (TUIO) become the industry standard when tracking blob data and operate as first layer for blob tracking framework such as CCV. TUIO is an open framework that defines a common protocol and application programming interface (API) for tangible multi-touch surfaces. Figure 6 shows the overview of TUIO. The TUIO protocol allows the transmission of an abstract description of interactive surfaces, including touch events and tangible object states. Depends on multi-touch gesture or tangible objects on the touch surface, the camera will detect and send the data to TUIO tracker application. After the coordinate and gesture of blob is translated into readable format for the framework, TUIO protocol will take place where the pass the raw data to the TUIO client application and produce the output on the display Figure 6 show the overview of TUIO.

In order to transfer the raw data, TUIO protocol will wrap the data and send to specific multi-touch application. However, a gateway as a channel for TUIO to

send the data to the application is needed. There are two different gateways which are Flash Open Sound Control (FLOSC) and Oscar. OSC is a protocol for communication among computers, sound synthesizers, and other multimedia devices that is optimized for modern networking technology. OSC is based on flash which is use to wrap the blob tracking data. Meanwhile, Oscar is an OSC-Flash bridge but developed for Apple Mac operating system. It purpose is to make Flash based applications communicate with other OSC and TUIO enabled devices. In this project, we will use FLOSC.

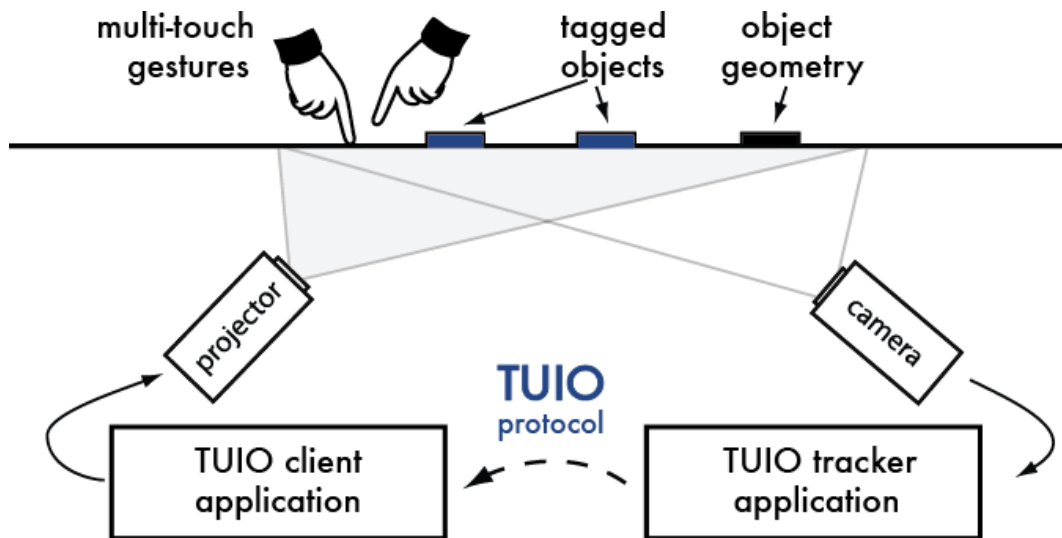


Figure 6 Overview of TUIO [11]

2.5 Application

There are many types of client that can be implemented with TUIO. Such as PyMT and MT4j. PyMT come from Python Multi-touch. In this client, it is purely based on python library. PyMT is an open source library for developing multi-touch applications. It is completely cross platform (Linux/OSX/Win) and released under the terms of the GNU GPL. Multi-touch for Java (MT4j) is an open source Java framework, created for rapid development of visually rich application. MT4j

is designed to support different kinds of input devices with a special focus on multi-touch support.

For early stage of building multi-touch, simulator comes handy. Simulator is software to simulate the desired environment within small scaled and control environment. Mainly, multi-touch developer will use TUIO Simulator. TUIO Simulator is based on Java framework. With the simulator, we can input the multi-touch gesture without using the actual hardware setup. Then, the simulator will communicate with the multi-touch application by TUIO protocol and display the desired result. Simulating the multi-touch gesture is important for developers of the multi-touch application in order to grasp their application output before publish the application. It capable of simulating any type of gesture within the mouse clicks and sends the data to the application.

2.6 Hardware

The performance of multi-touch heavily depends on the selection of components. Therefore, it is very important to carefully choose the components. The most important device in this setup is the camera. The camera will act as input register. Hence, the camera must able to track the fast pace blob for smooth touch experience. Normal webcam is limited with low frame rate and resolution. The frame rate is the number of captured frames within a second. In order to cope with the fast pace of the blob, camera with at least frame rate of 30 FPS (frame per second) is recommended. However, the system will requires a system that can handle image processing and blob tracking at 30 FPS. Therefore, SONY PS3 Eye camera is used. Figure 7 shows the SONY PS3 Eye camera. The higher the resolution, the more pixel can be detected by the camera. This is very important for accuracy and precision of the multi-touch device. Larger touch plane require higher resolution in order to cope with the blob tracking. As low as 320 x 240 pixels is sufficient for small touch plane and 640 x 480 pixels for large touch plane. Figure 8 shows the FPS achieved by SONY PS3 Eye camera.



Figure 7 SONY PS3 Eye camera [12]



Figure 8 SONY PS3 Eye camera FPS

2.7 Advantages and Disadvantages

There are several advantages of the multi-touch technology which will change on how computer-human interaction in the future. Compare to pointing devices such as mouse or stylus, direct contact with fingers is considered interesting and attractive method for providing human-computer interaction. With the interaction and display surfaces on the same surface, no extra input control device is necessary for the interaction. [13] The ability to detect multi-input at once allows the design of high-degree-of-freedom in interaction which takes advantages of people's real world manipulation abilities. Rapid learning curves with high degree of robustness make multi-touch is the best and ideal interface for interaction [14] such as information kiosk, automated teller machine and vending machine thus also lead to wide of multi-touch application for mobile world.

Since multi-touch required wide range of arm and hands movement, it will lead to arm fatigues in the long term. User's fingers and arm movement also lead to low selection precision when pointing at targets that are smaller than finger's width [8]. It was reported that the accuracy of interaction varied from 66.7% for targets of 10mm per side, to 99.2% for targets of 26mm and the accuracy was maximized once targets were approximately 26mm per side [15]. Most of the large multi-touch interface, the object is simply out of reach and most of the interaction widgets are bigger than finger's width which leads to low selection precision [16].

CHAPTER 3 METHODOLOGY

3.1 Procedure Identification

The scope of this project and flow of task for FYP I and FYP II are envisaged as in the following flow chart shown in Figure 9 and Figure 10 respectively.

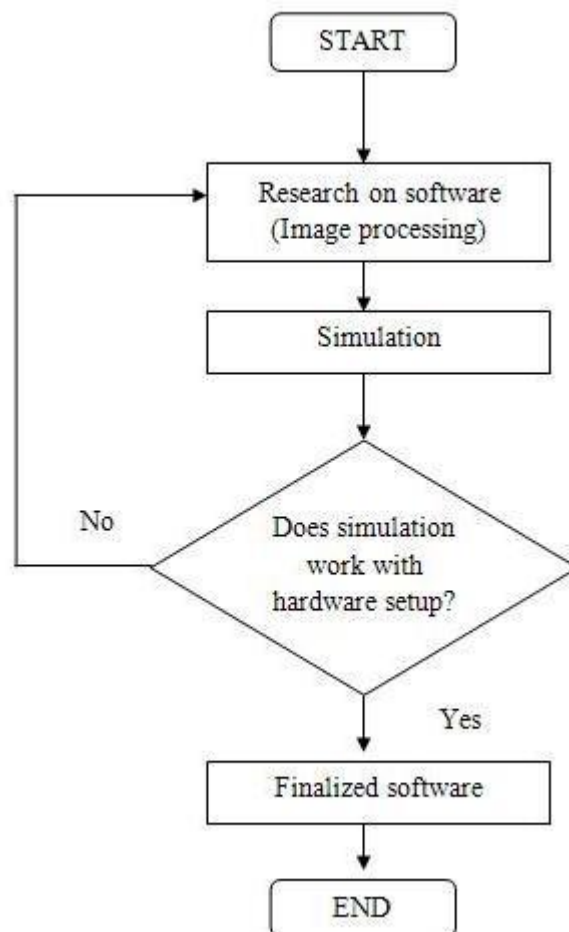


Figure 9 FYP I flow chart

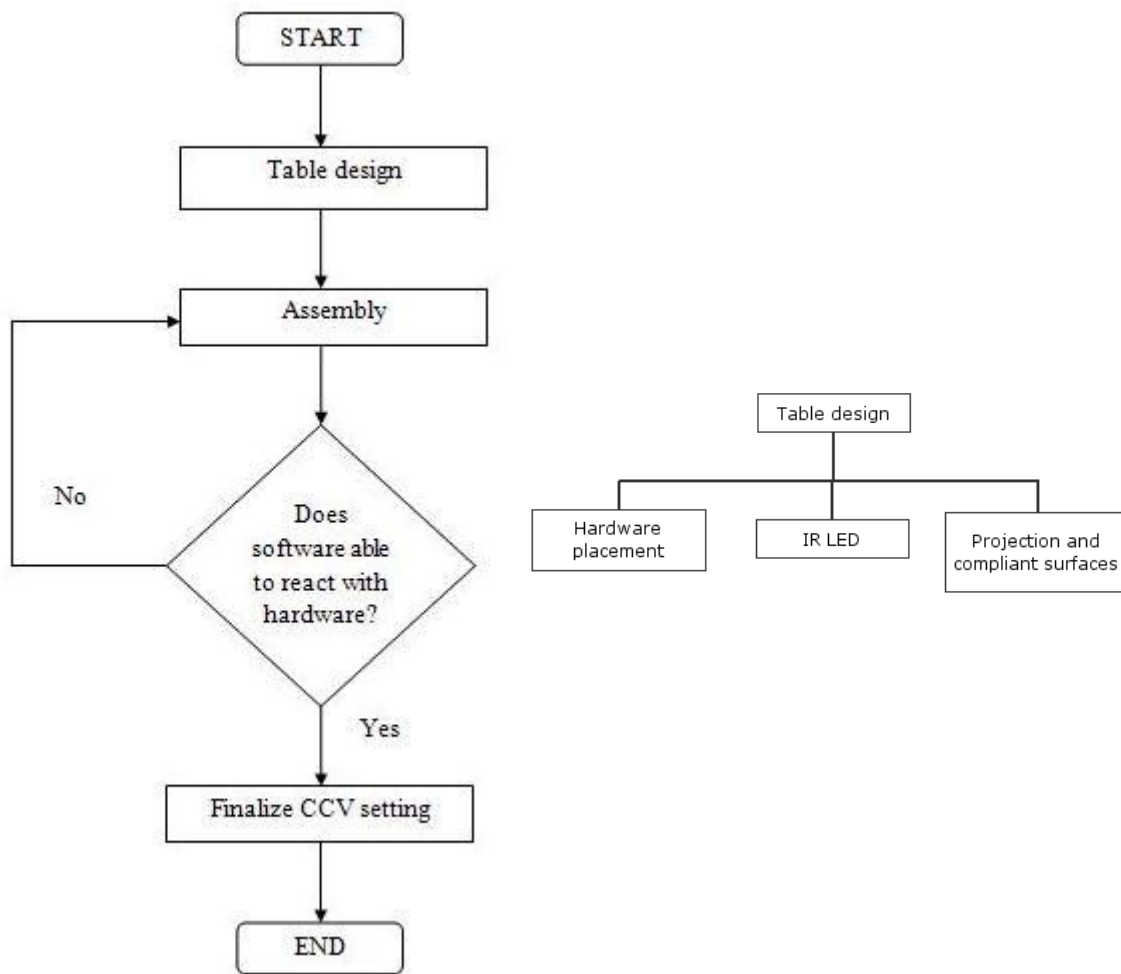


Figure 10 FYP II flow chart

The overall flow of the project can be partitioned into the following steps:

3.2 Research on Software

CCV can interface with various web cameras and video devices as well as connect to various TUIO/OSC enabled applications and supports many multi-touch lighting techniques including: FTIR, DI, DSI, and LLP with expansion

planned for the future vision applications. With the multi-purpose tracking, CCV is the leading blob tracker in multi-touch technology.

There are several features that makes CCV is the best choice. CCV offers simple graphical user interface (GUI), wide choice of filters, dynamic mesh calibration and network broadcasting. Figure 11 show the CCV GUI. With the simple GUI, the interface is more intuitive and easier to use. Since CCV offer wide choice of filters, CCV will almost work with any multi-touch setup such as FTIR, DSI, LLP and others. Since the project might change to bigger display, it will take a lots of works to calibrate the touch surface if the blob tracker unable to compensate with changes of size. However, CCV can vary the calibration points for smaller or larger display while maintaining the same speed and performance. Lastly, the most important is the network broadcasting features. It is very important because with the network broadcast features, CCV able to send OSC TUIO message directly for the quick setting. Table 1 shows CCV features in details. This will make our simulation less complicated compare to other blob tracker which does not provide the network broadcast module.

In order to CCV works, it must configure first. The goal is to have a final tracked image that has white blobs coming from fingers or objects placed on the touch surface (with no background noise or false blobs visible or tracked).

3.3 Simulation

The configuration can be adapted when CCV able to detect the blob clearly without any unwanted image count as blob. Therefore, the experiment or modification based on CCV setting is important. After the best setting for CCV is acquired, enable FLOSC (Figure 12) or Oscar (Figure 13) server to run is a must in order to CCV interact with the application. After FLOSC server is running, CCV will be able to send TUIO protocol to specific application. Application for the demo purpose can be run in order to simulate the multi-touch. There are many

applications which have been developed such as Touch Worldwind plugin and Tdesk.

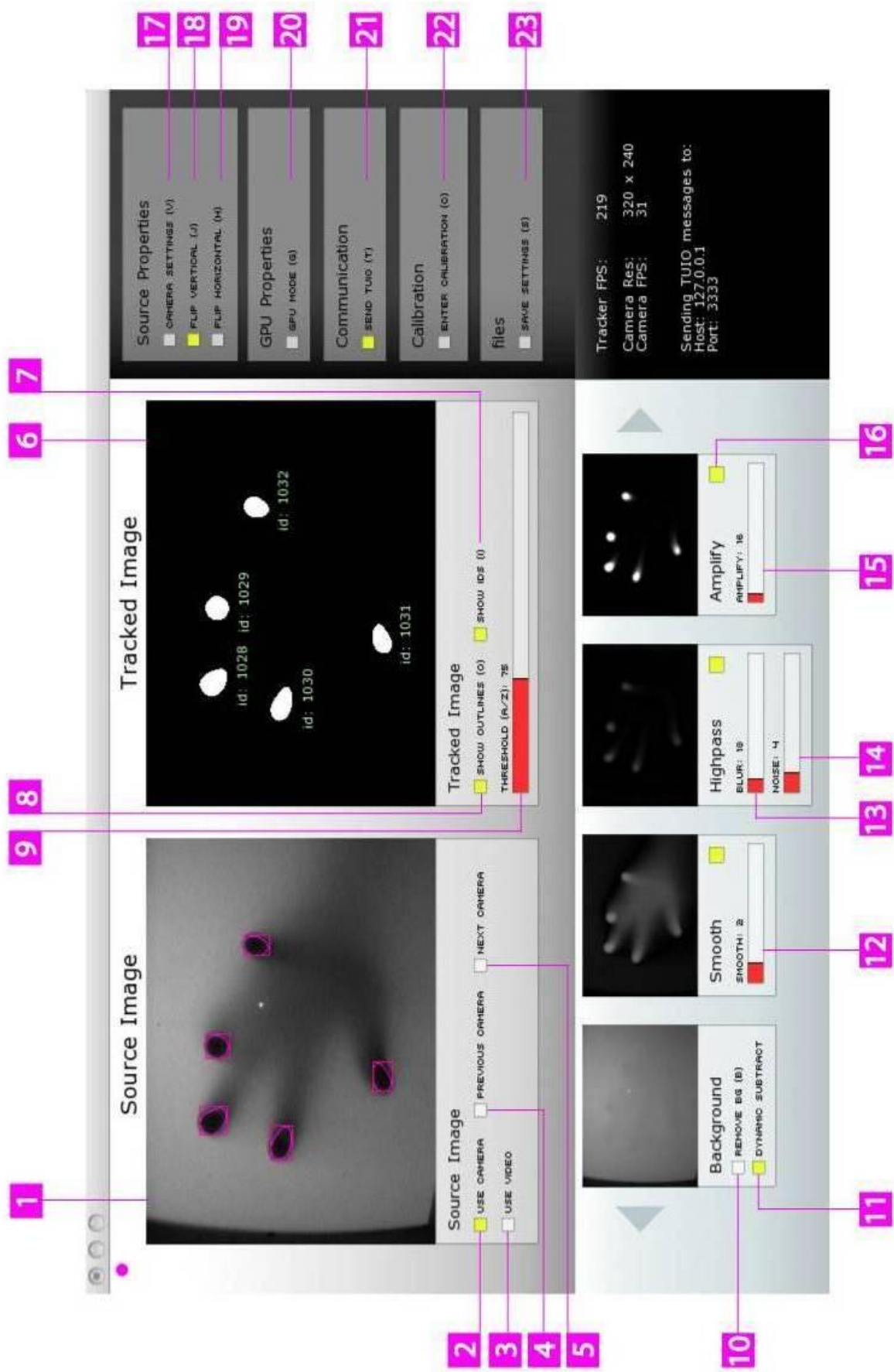


Figure 11 CCV GUI [17]

Table 1 CCV features

No	Parameter	Function
1	Source Image	Displays the raw video image from either camera or video file
2	Use Camera Toggle	Sets the input source to camera and grabs frames from selected camera.
3	Use Video Toggle	Sets the input source to video and grabs frames from video file
4	Previous Camera Button	Gets the previous camera device attached to computer if more than one is attached.
5	Next Camera Button	Gets the next camera device attached to computer if more than one is attached.
6	Tracked Image	Displays the final image after image filtering that is used for blob detection and tracking.
7	Show IDs Toggle	Show the ID numbers for each tracked blob.
8	Show Outlines Toggle	Show pink outlines around fingers on source image.
9	Threshold Slider	Adjusts the level of acceptable tracked pixels. Pixels less than the threshold value will be removed and pixels above the threshold value will be detected and tracked.
10	Remove Background Button	Captures the current source image

		frame and uses it as the static background image to be subtracted from the current active frame. Press this button to recapture a static background image.
11	Dynamic Subtract Toggle	Dynamically adjusts the background image. Turn this on if the environmental lighting changes often or false blobs keep appearing due to environmental changes
12	Smooth Slider	Smooths the image and filters out noise (random specs) from the image.
13	Highpass Blur Slider	Removes the blurry parts of the image and leaves the sharper brighter parts.
14	Highpass Noise	Filters out the noise (random specs) from the image after applying Highpass Blur
15	Amplify Slider	Brightens weak pixels. If blobs are weak, this can be used to make them stronger.
16	On/Off Toggle	Used on each filters, this is used to turn each filter on or off.
17	Camera Settings Button	Opens a camera settings box.
18	Flip Vertical Toggle	Flips the source image vertically.
19	Flip Horizontal Toggle	Flips the source image horizontally.
20	GPU Mode Toggle	Turns on hardware acceleration and uses the GPU. This is best used on

		newer graphics cards only.
21	Send TUIO Toggle	Turns on the sending of TUIO messages.
22	Enter Calibration	Loads the calibration screen.
23	Save Settings	Saves all the current settings.

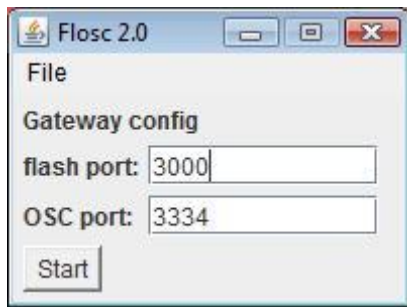


Figure 12 FLOSC



Figure 13 Oscar

3.4 Table Design

Before the project proceed with the real setup, it is important to design the table according to the real specification such as projector throw distance. For the design purpose, SimProj Project is used. The software is developed by Ben Kupperts. It is Java based, open source and provide simple GUI for users to design the multi-touch table. One of the important feature for this software is, it integrate projector throw ratio. Therefore, the software is able to provide accurate measurement for the table since the table design is heavily depends on projector throw ratio.

Based on X1161 specification, Figure 14 shows the design by using SimProj Project.

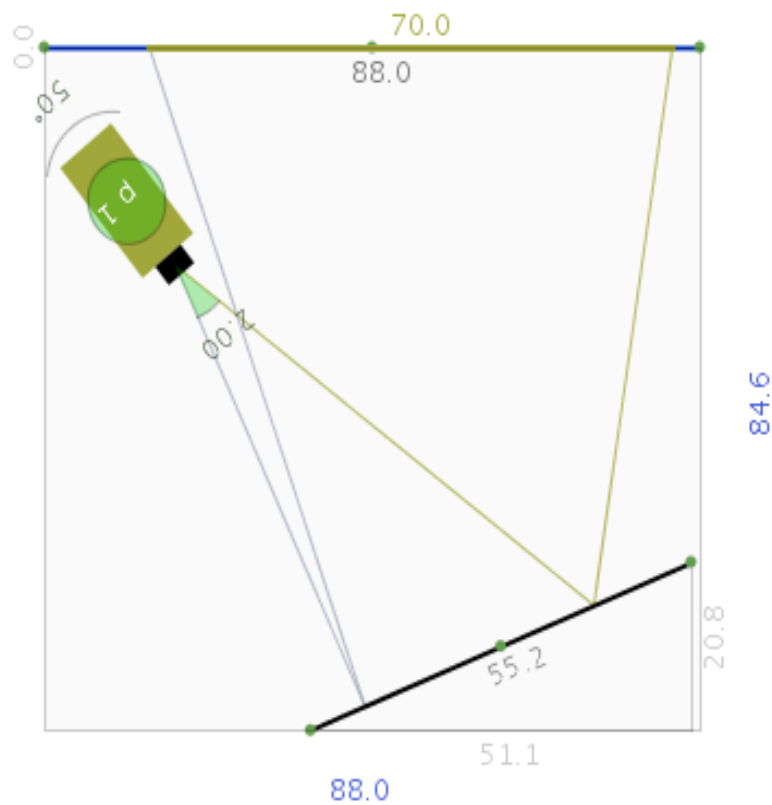


Figure 14 Table design using SimProj Project

Since the throw ratio for X1161 is quite high, therefore, in order to achieve big images without increasing the table height, a mirror is placed at the bottom of the table to reflect the projection towards the projection screen. The expected image size from the projector is shown by Figure 15.

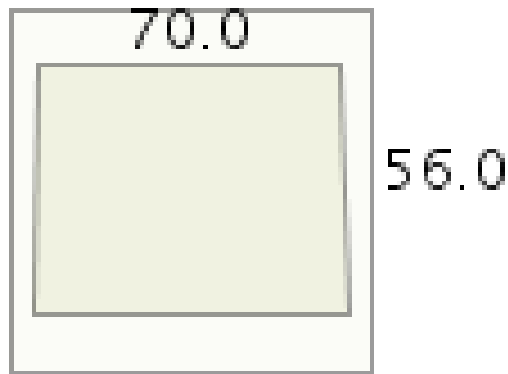


Figure 15 Expected size of the image

3.5 Camera

Since this project is based on input from Infrared (IR), the camera must be able to take IR as its inputs. However, it depends on the lens type. Most of the normal camera lenses are unchangeable because the lenses are fixed to the camera.

However, SONY P3S Eye camera lens is interchangeable where the lenses can be removed and placed with different types of lenses. In this project, m12 mount (Figure 16) with varifocal lenses (Figure 17) is used. Despite SONY PS3 Eye being developed mainly for PS3 console, however, there is a group of community who works on SONY PS3 Eye camera driver for Microsoft Windows, Mac OS X and

Linux [16]. Without the driver, the operating system is unable to detect the camera.

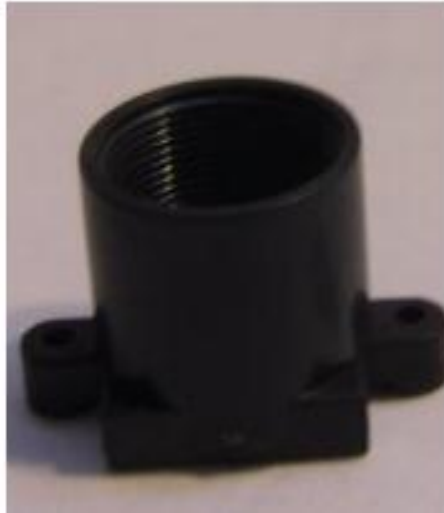


Figure 16 m12 mount [18]



Figure 17 Varifocal lens [18]

3.5.1 Camera Modification

In order for SONY PS3 Eye camera to be able to take IR as input, several modifications must be made. There are:

- Replace visible light filter with IR filter.
- Change camera lenses.
- Replace lenses mount with m12 mount.

The first two modifications can be simultaneously done since visible light filter is attached to the camera lenses. A standard camera lens is replaced by varifocal lenses. As it names, varifocal, the lens has wide focus option ranging from 2.8mm until 12mm. This is an advantage compare to the standard lenses because the camera will be able to detect inputs from different height. Since camera lenses came with standard mount, the standard mount must be replaced with m12 mount in order to replace camera lenses. Figure 18 shows standard lenses with varifocal lens side by side.



Figure 18 Varifocal lenses on the left side and standard lenses on the right side

There are several steps to be taken in order to disassemble the camera and change the lenses. First, remove all the screw at the back of the camera and take out the camera board. Refer Figure 19. Next, take out the case of the camera so the lens will be able to be removed as shown in Figure 20.



Figure 19 Camera without rear plastic case



Figure 20 Camera with standard lenses

Figure 21 shows camera board without the standard lenses. Place varifocal lens with the m12 mount and assemble the camera with the plastic case. Figure 22 shows the complete modification to the camera.



Figure 21 Camera board



Figure 22 Camera with varifocal lens

Without IR filter, camera will not able to detect IR input from the user. Therefore, visible light filter from the camera will be replace by IR filter and place

in front of the varifocal lens. Figure 23 shows modified SONY PS3 Eye camera with varifocal lens and IR filter.



Figure 23 SONY PS3 Eye camera with IR filter and varifocal lens

3.6 Compliant and Projection Surfaces

The compliant surface overlay is used to describe an overlay placed above the acrylic. The compliant surface overlay needs to be made of a material that will "couple" with the acrylic surface under pressure and set off the FTIR effect, and then "uncouple" once the pressure is released [19]. However, in this project, compliant surface is used as projection screen because of the cost constraint.

There are several advantages of using compliant surface such as it is sensitive to the pressure and give better result in dragging movement of the inputs from the user. The IR inputs from the interaction of the users are able to reflect better with the present of compliant surfaces. Since it is pressure sensitive, compliant surface plays important roles in multi-touch response to the inputs because of the better IR reflection.

3.6.1 Materials

There are two setup for the compliant surface which are silicon mixed with thinner (turpentine) and silicon. For the time being, both setups are in the experiment phase where the setup of the compliant surface to be use with the full scale project is still undecided. The main criteria for the compliant surface selection:

- clean surface
- able to reflect IR source without a leaving a trace
- able to act as projection surface without distorting the images

In this project, tracing paper will act as compliant and projection surface. Silicon will be applied at one side of the tracing paper. Therefore, the silicon must be as clear as possible to allow projection from the projector to pass through to the thin silicone layer. Hardex 100% Clear Silicon Rubber Sealant with turpentine is used in this project. Refer Figure 24 for the products.



Figure 24 Silicon rubber with turpentine

3.6.2 Tinkerman's Method

One of the popular methods to create effective compliant surface is Tinkerman's method. Tinkerman's method use rolled on application where the mixture of silicone and thinner are rolled on the tracing paper. Thus, after the silicone is cure about 3 until 5 hours, another layer of silicone is applied on the tracing paper. 3 layers of silicone are preferred for maximum effect of the compliant surfaces.

3.6.2.1 Silicon without Thinner

This is the first setup of the compliant surfaces. The expected result of the silicon surface is, it will become a rough surface because the absence of thinner. The silicon is applied directly onto the tracing paper (Figure 25) and rolled on using foam paint roller.



Figure 25 Silicon is applied directly onto tracing paper

After 3 layers of silicone were applied, Figure 26 shows the result. As expected, the surface becomes rough.

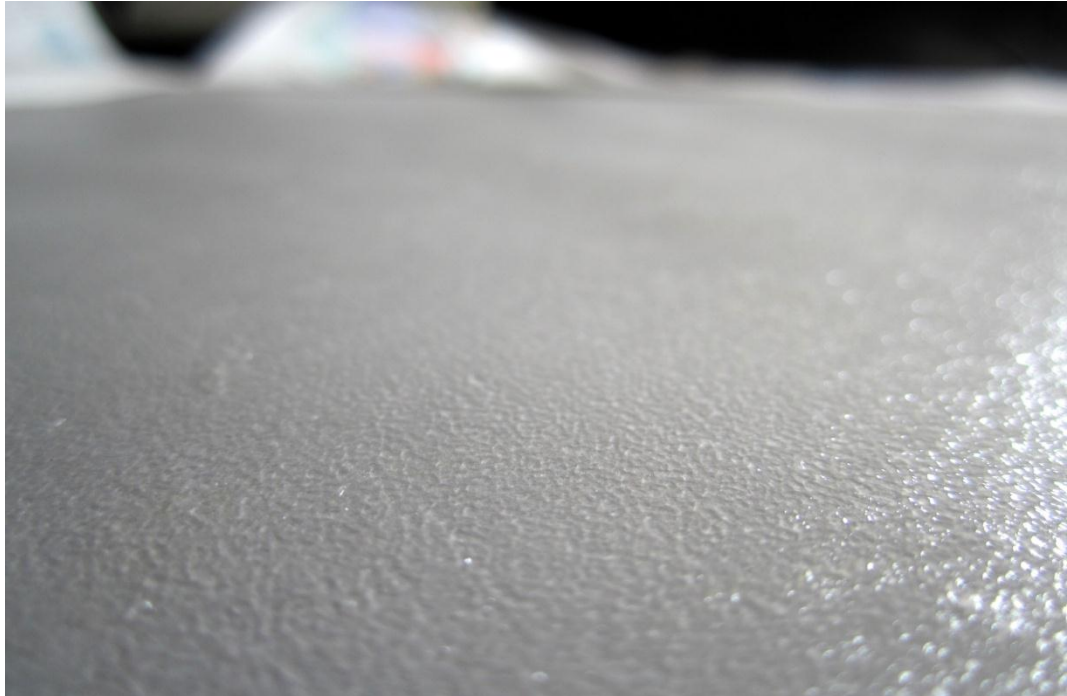


Figure 26 Result of silicon without thinner after 3 layers

3.6.2.2 Silicon with thinner (turpentine)

Another setup of the compliant surface is to mix silicone with thinner. The thinner will react with the silicone and produce smooth surface compare to silicone without thinner setup. After the silicone is mix with thinner, the mixture were poured on the tracing paper and rolled on until thin layer of the mixture were created. Figure 27 shows the process of applying silicone with thinner onto the tracing paper.

Figure 28 shows the final result of the setup. From the figure in the next page, there are obvious different in both setup. For the silicone and thinner mixture setup, it produces smooth surface compare to the silicone applied directly onto the tracing paper.



Figure 27 Mixture of silicon with thinner applied onto the tracing paper



Figure 28 Smooth surface of the silicon and thinner mixture setup

Both of the setup will be test after the prototype is nearly completion. However, due to the result of the both setup, direct silicon application is likely to be used as projection and compliant surfaces.

3.7 Projector

The most suitable projector for this project is the projector which has short throw capability. Short throw projectors have very short throw ratios, the distance from projector to screen compared to the screen size. For example, a projector with a 1.5:1 throw ratio would have to be 7.5 feet back to project a 60-inch diagonal image [20]. Refer to Figure 29 for short throw illustration.

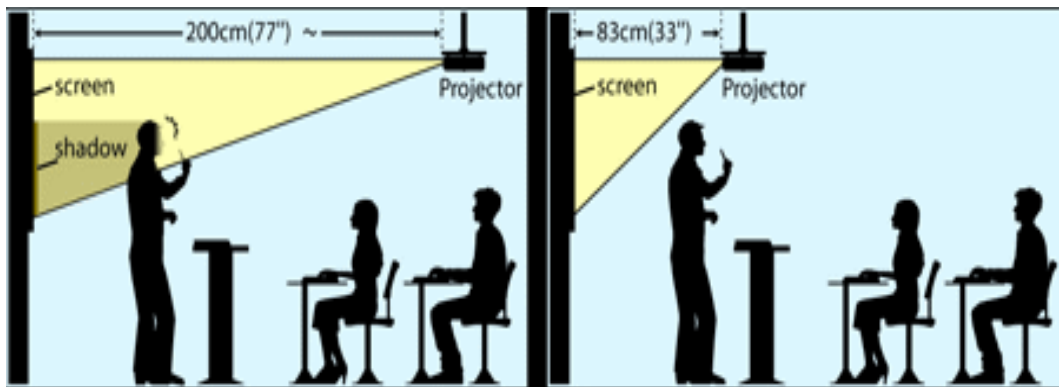


Figure 29 Standard projector on the left side. Short throw projector on the right side [21].

If the short throw projector is used in this project, a small projection surface with small table could be build. The projector will capable to produce larger image with shorter distance. However, the cost for short throw projector is slightly higher compare to standard projector.

In this project, Acer X1161 3D projector is used. Refer Figure 30 for the X1161 picture. The selection of X1161 are depends on the cost and projection throw distance. From the Figure 31, it shows that X1161 have throw distance in

between 1.5m until 12m for image up to 770cm in diagonal size. Hence, 1.5m throw distance is sufficient in order to build compact multi-touch table.



Figure 30 Acer X1161 3D Projector [22]

Street Price (USD) : \$429	3D Projector: 3D Ready
MSRP (USD) : **	Compatibility:
Brightness (Lumens) : 2500 ANSI	HDTV: 720p, 1080i, 1080p/60
<i>Eco-Mode (Lumens):</i> 2000 ANSI	576i, 576p
Contrast (Full On/Off) : 4000:1	EDTV/480p: Yes
Variable Iris: No	SDTV/480i: Yes
Audible Noise: 30.0 dB	Component Video: Yes
<i>Eco-Mode:</i> 26.0 dB	Video: Yes
Weight: 2.2 kg	Digital Input: No
Size (cm) (HxWxD) : 8 x 27 x 19	Computers: Yes
Std. Lens: <i>Focus:</i> Manual	Display: <i>Type:</i> DLP (1)
<i>Zoom:</i> Manual, 1.10:1	<i>Color Wheel Segs:</i> **
Throw Dist (m) : 1.5 - 12.0	<i>Color Wheel Speed:</i> **
Image Size (cm) : 86 - 770	<i>Native:</i> 800x600 Pixels
<i>Optional Lenses:</i> No	<i>Maximum:</i> 1920x1080 Pixels
	<i>Aspect Ratio:</i> 4:3 (SVGA)

Figure 31 Acer X1161 3D specification [23]

3.8 Frame

The next step is to build the frame to hold the acrylic. In this project, aluminum frame will be used because of several aspects such as:

- Light weight
- Easy to drill and cut
- Available locally

Although from the design above shows about 70.0cm x 56.0cm for the projection surface, since we use A2 size tracing paper, the projection surface will vary according to the projection surface. Figure 32 shows the dimension of the A2 tracing paper. Therefore, the dimension of the aluminum frame will be referred to size of A2 tracing paper dimension.

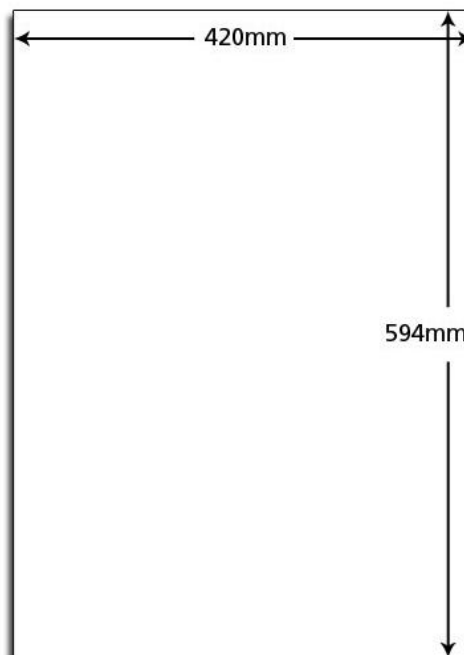


Figure 32 A2 dimension [24]

Aluminum "L" shape bar is used in this project. Refer to Figure 33. After the aluminum bar is cut into the required dimension, the bars undergo milling process in order to place the IR LED through the aluminum bar. Since each IR LED must have a gap about 1 inch between each IR LED, milling is preferred than conventional drilling because of the precision issue. With milling machine, it have digital meter and easy for user to achieve the required gap. Refer Figure 34 for milling machine digital meters.

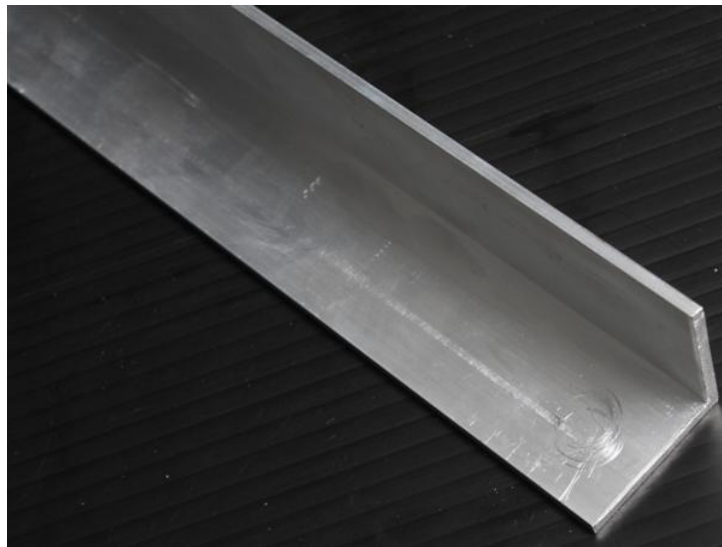


Figure 33 Aluminum "L" shape bar



Figure 34 Milling machine digital meters

With the digital meters, precise 1 inch gap between IR LED can be achieved. The dimension will be the same as A2 tracing paper dimension. Figure 35 and 36 shows the milling process.



Figure 35 Aluminum bar undergo milling



Figure 36 IR LED holder after milling

The next step after milling is to put the aluminum pieces together and form a frame. Rivet is used in order to join the aluminum. In order to place IR LED around the hole, adhesive glue is used to give better grip in holding the LED. There is no known effect in using adhesive glue with LED. Figure 37 shows the glue curing process.

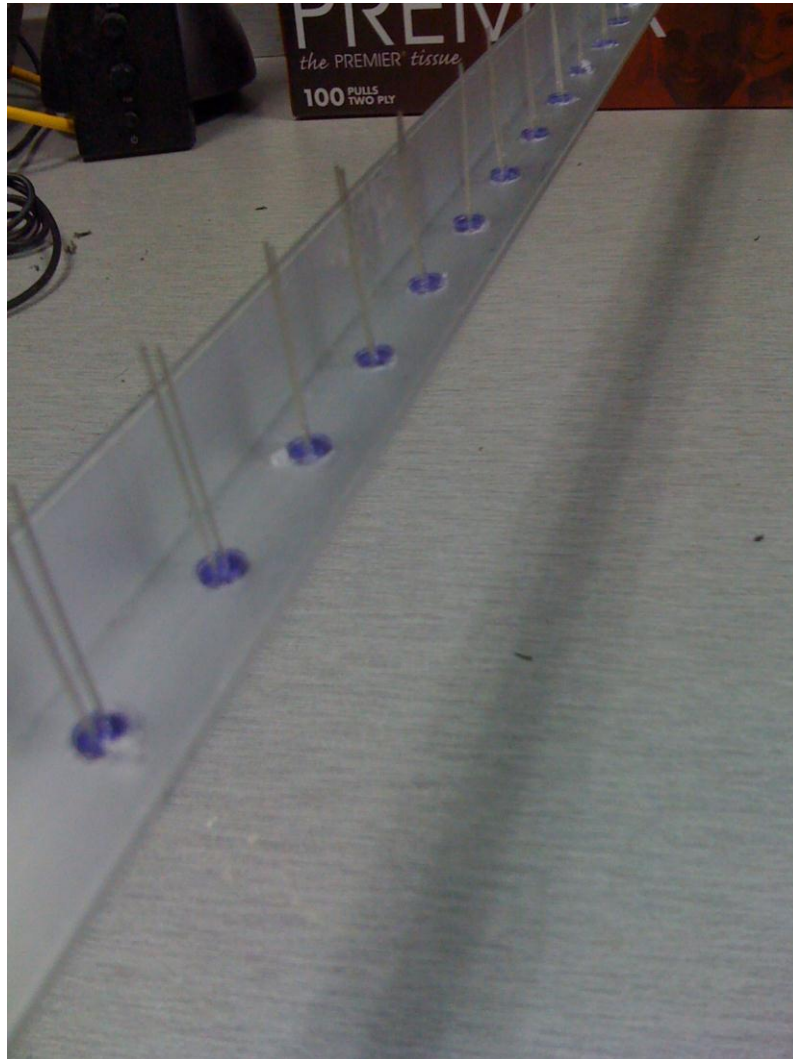


Figure 37 Glue curing process

After the cure process, each of the LED will place in 4 set in parallel connection with 12V source from the power adapter. Series connection is not preferred because of the complexity issue arise when if one of the LED in series burnt, the rest of LED will not operate. Any connection issues can be easily detected and troubleshoot with parallel connection. Figure 38 shows the schematic diagram of LED with parallel connection.

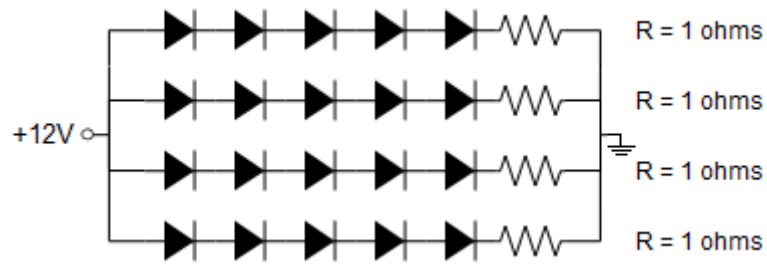


Figure 38 IR LED Wiring Schematic

One aluminum frame will consist of 20 IR LED. However, since the optimum result of the touch surface is benefit from full sided IR LED around the edges, a total of 4 aluminum frame are place around the touch surface which a sum of 80 IR LED. Therefore, the wiring of IR LED is important in order to prevent from any shortage of power supply or short circuit. Figure 39 shows the complete 4 aluminum frame and Figure 40 shows the powered IR LED.



Figure 39 Wired aluminum frame

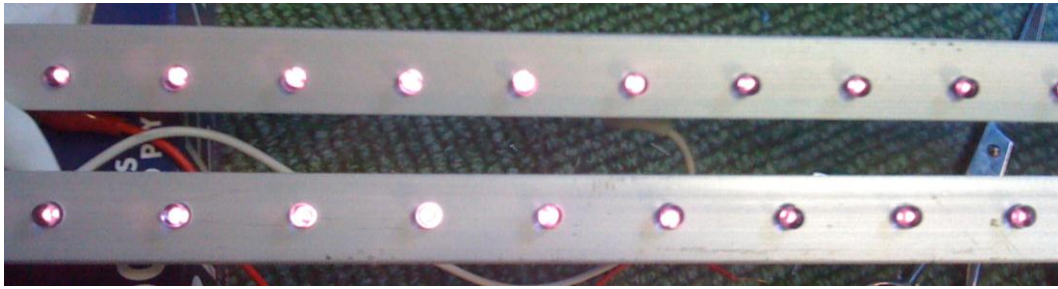


Figure 40 Functioning IR LED

IR LED light ray cannot be detected by naked eyes. In order to make sure that IR LED is functioning, normal camera or IR camera can be used. However, surrounding or environment light can reduce the visibility of IR light rays. Since the multi-touch is considered closed box, it perform well for the multi-touch. With 4 IR LED aluminum frame is placed around the edges of touch surface, more IR trap in the surface thus lead to better performance. From the observation, 2 IR LED aluminum frame did not perform well in frustrating the IR because lack of IR trapped inside the surface. Figure 41 shows the placement of the frame with touch surface.

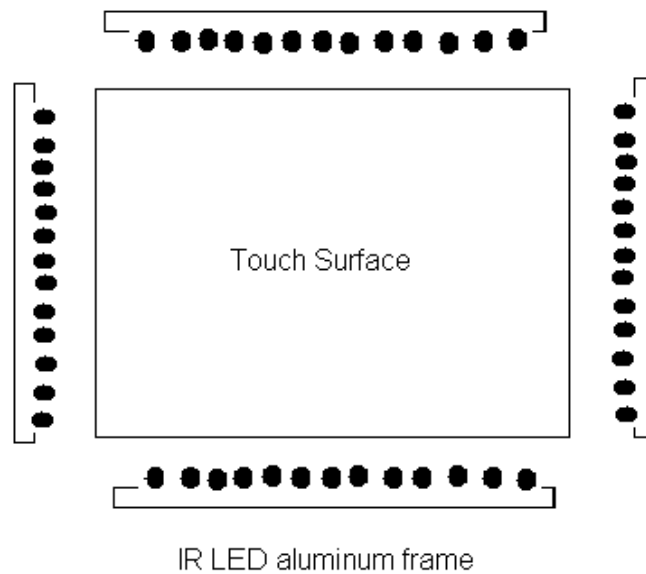


Figure 41 IR LED aluminum frame placement

3.9 Software and Hardware Used

Table 2 Software and Hardware Used

Software	Hardware
Community Core Vision (CCV)	IR LED
TUIO Simulator	Plywood
Smoke	Projector
Code Laboratories PS3 Eye Driver	Acrylic
	Aluminum Frame
	Mirror
	SONY PS3 Eye Camera

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

There are two separate results for this project. First, result for simulation phase and second, result for the hardware setup. In the simulation phase, CCV 1.3 and smoke application was selected. The following results are obtained:

- Combination of CCV 1.3 and smoke application show that, camera, blob tracker and TUIO protocol were able to do the task.
- Optimum setting for blob tracking was obtained
- Simulation application able to detect TUIO input
- Camera able to detect input from touch surfaces

For the hardware setup, the camera able to take IR as input. Most of the hardware needs to build the table are available in local store. However, several item such as varifocal lens and m12 mount are not available locally. Since there are a lot of developers active in multi-touch, lenses and m12 mount were ordered from other developers.

4.1.1 CCV Setting Optimization

In order to achieve best blob tracking, CCV setting need to be configured to detect as much as accurate blob as possible. Table 3 in the next page shows the features that give the big effect to the blob tracking only. From the try-and-error method, Table 2 shows the best and worst setting for CCV.

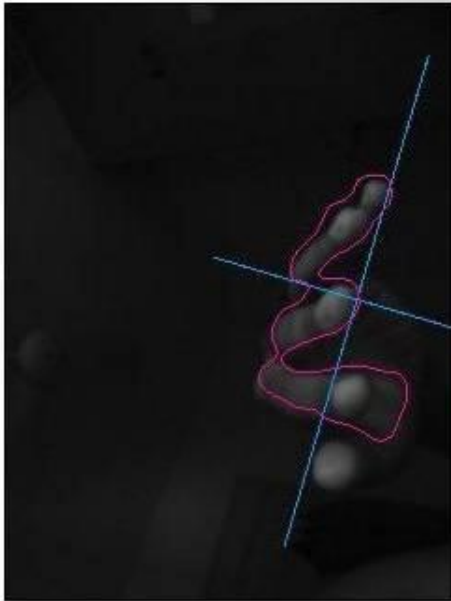
Table 3 Best and Worst CCV Setting

No	Feature	Worst	Best
1	Image threshold	63	63
2	Movement filtering	2	2
3	Min blob size	250	15
4	Max blob size	457	86
5	Blur	85	27
6	Amplify	103	38

Figure 42 and 43 show the result from the setting shown in Table 3. Meanwhile, Figure 44 and 45 shows the best setting applied to IR LED with and without IR filter.

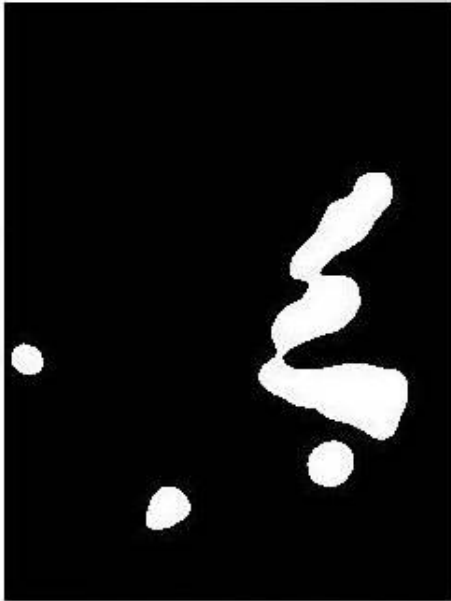
Community Core Vision

Source



Source Image SHOW OUTLINES (O) SHOW IDS (I)
 USE CAMERA PREVIOUS CAMERA NEXT CAMERA
 USE VIDEO

Tracked



Tracked Image INVERSE
 IMAGE THRESHOLD: 63 MOVEMENT FILTERING: 2
 MIN BLOB SIZE: 250 MAX BLOB SIZE: 457

Background

 REMOVE BG (B)
 DYNAMIC SUBTRACT
 LEARN SPEED: 59

Smooth

 SMOOTH: 0

Highpass

 BLUR: 85
 NOISE: 9

Amplify

 AMPLIFY: 103

Camera Properties
 CAMERA SETTINGS (V)
 FLIP VERTICAL (J)
 FLIP HORIZONTAL (H)

GPU Properties
 GPU SHADERS (G)

Communication
 TUIO UDP (T)
 FLASH XML (F)
 BINARY TOP (N)

Calibration
 ENTER CALIBRATION (C)

Settings
 SAVE SETTINGS (S)

Calculation Time: 3 ms
 Camera Resolution: 320 x 240
 Camera Framerate: 61 FPS

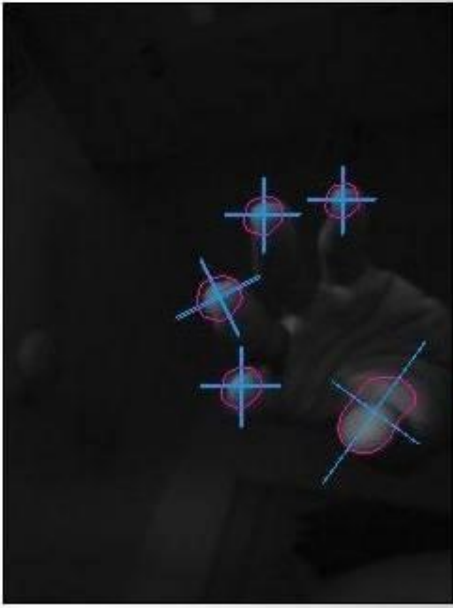
Press spacebar for mini mode

www.nuigroup.com/ccv - 1.3

Figure 42 Worst setting

Community Core Vision

Source

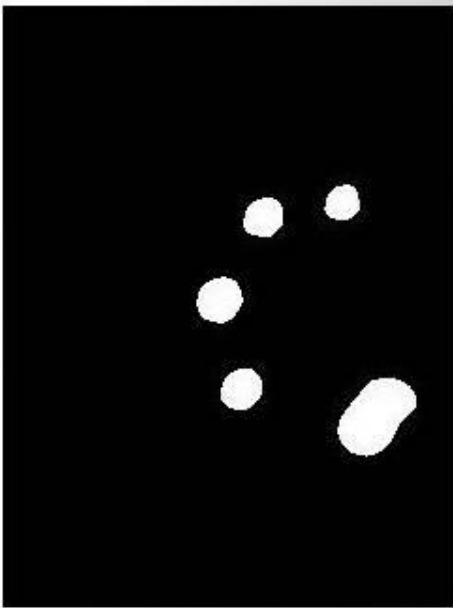


Source Image SHOW OUTLINES (O) SHOW IDS (I)

USE CAMERA PREVIOUS CAMERA NEXT CAMERA

USE VIDEO


Tracked



Tracked Image INVERSE

IMAGE THRESHOLD: 63 MOVEMENT FILTERING: 2

MIN BLOB SIZE: 15 MAX BLOB SIZE: 96




Background

REMOVE BG (B)


DYNAMIC SUBTRACT

LEARN SPEED: 28



Smooth

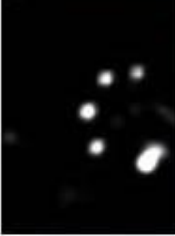
SMOOTH: 0



Highpass

BLUR: 27

NOISE: 9



Amplify

AMPLIFY: 38

Calculation Time: 4 ms

Camera Resolution: 320 x 240

Camera Framerate: 61 FPS

Press spacebar for mini mode

www.nuigroup.com/ccv - 1.3

Camera Properties

CAMERA SETTINGS (V)

FLIP VERTICAL (J)

FLIP HORIZONTAL (H)

GPU Properties

GPU SHADERS (G)

Communication

TUIO UDP (T)

FLASH XML (F)

BINARY TCP (N)

Calibration

ENTER CALIBRATION (C)

Settings

SAVE SETTINGS (S)

Figure 43 Best setting

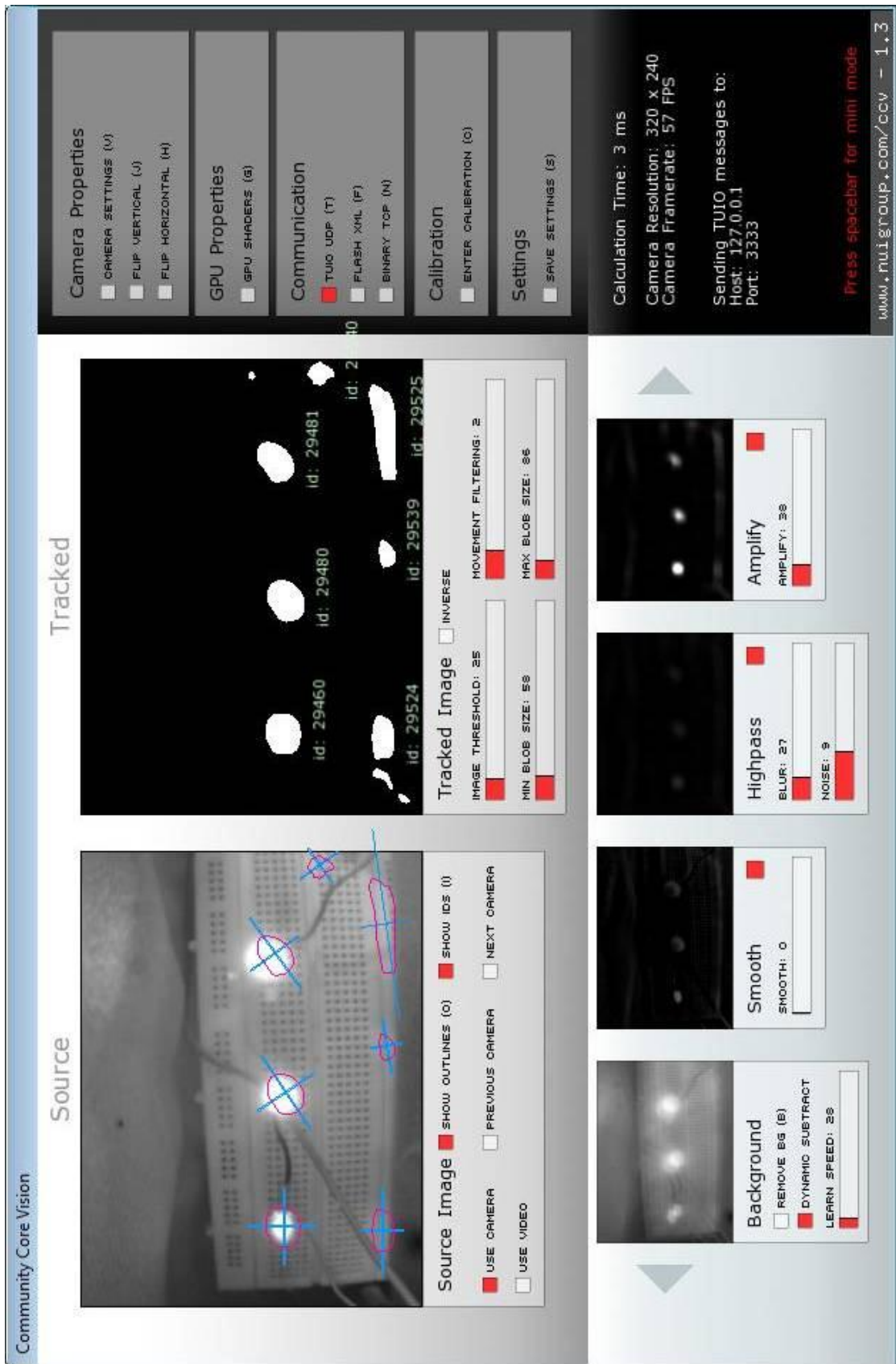
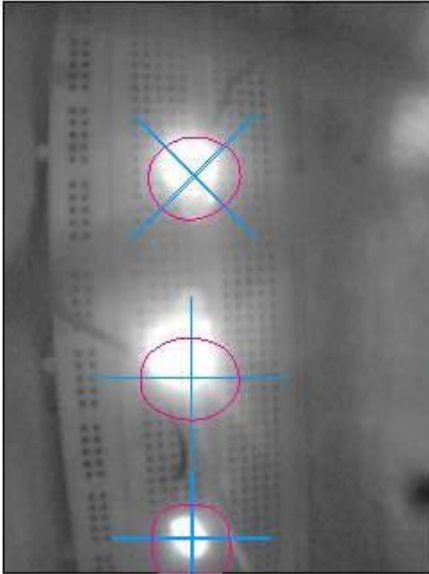


Figure 44 False blob detected by the camera. Without IR filter

Community Core Vision

Source

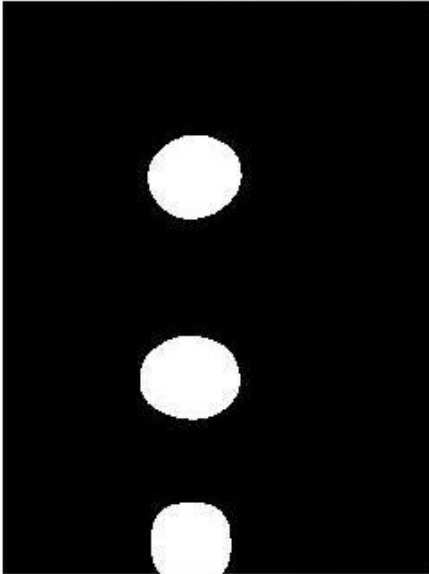


Source Image SHOW OUTLINES (O) SHOW IDS (I)

USE CAMERA PREVIOUS CAMERA NEXT CAMERA

USE VIDEO

Tracked



Tracked Image INVERSE

IMAGE THRESHOLD: 91 MOVEMENT FILTERING: 7

MIN BLOB SIZE: 186 MAX BLOB SIZE: 493

Background

REMOVE BG (B)

DYNAMIC SUBTRACT

LEARN SPEED: 28

Smooth

SMOOTH: 8

Highpass

BLUR: 58

NOISE: 20

Amplify

AMPLIFY: 38

Camera Properties

CAMERA SETTINGS (V)

FLIP VERTICAL (J)

FLIP HORIZONTAL (H)

GPU Properties

GPU SHADERS (S)

Communication

TUIO UDP (T)

FLASH XML (F)

BINARY TOP (N)

Calibration

ENTER CALIBRATION (C)

Settings

SAVE SETTINGS (S)

Calculation Time: 4 ms

Camera Resolution: 320 x 240

Camera Framerate: 60 FPS

Sending TUIO messages to:
Host: 127.0.0.1
Port: 3333

Press spacebar for mini mode

www.nuigroup.com/ccv - 1.3

Figure 45 Accurate blob detection with IR filter

Previous figures are based on simulation and minimal hardware setup. Before continue with full scale hardware setup, CCV parameter need to be set according to table dimension. The most important parameter in hardware setup is, amplify field. In this setup, the amplify value is quite high because of the weak blob detection.

4.2 Discussion

The effect of weak blob detection occurred when the camera cannot detect the input according to the figure movement. The gesture or movement of the fingers did not couple or frustrated enough the IR hence lead to Figure 46 shows the simulation with CCV and smoke application as multi-touch application. From the smoke application, there is purple glow where it received the input from CCV. CCV able to detect the fingertip and the result is show at the Tracked section.

With the new current hardware setup, 4 IR LED aluminum frame around the touch surface and cameras placed below the touch surface (refer Figure 2), Figure 47 shows table without any input and Figure 48 shows the full effect of FTIR with inputs.

The cost of current project is shown in Table 3.

Table 4 Current cost for the project

No.	Item	Quantity	Price per item (RM)	Total (RM)
1.	Acer X1161 3D	1	1888	1888
2.	Green L 43mm IR Filter	1	60	60
3.	OSRAM IR LED	60	1.45	87
4.	m12 mount	1	60	60
5.	Varifocal lenses	1	200	200
6.	50cmx50cm mirror	1	16	16
7.	Soft laminate	2	10	20
8.	Tools	1	39.50	39.50
9.	Soft laminating	1	20	20
10.	Plywood	2	50	100
				2430.50

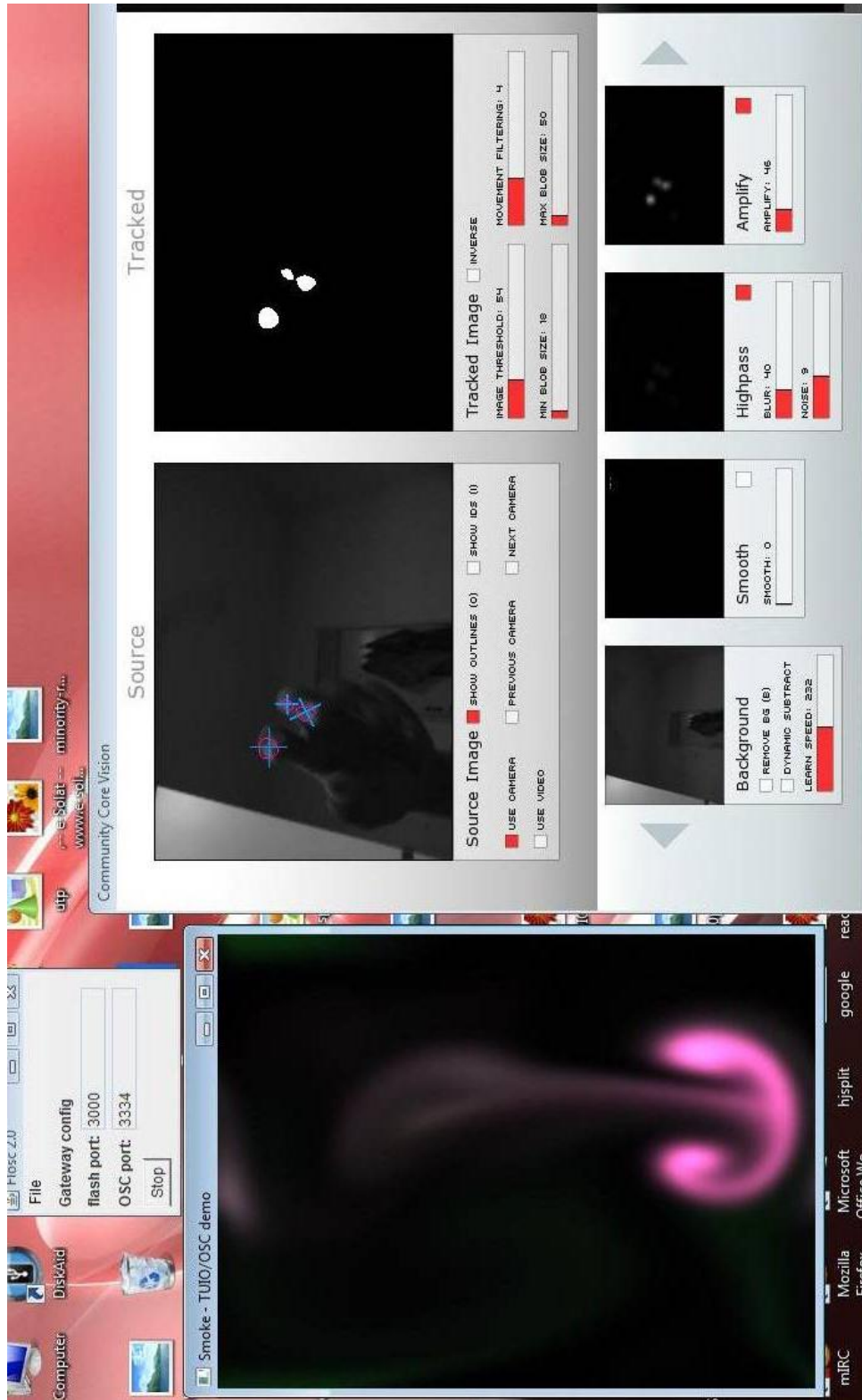


Figure 46 Final simulation

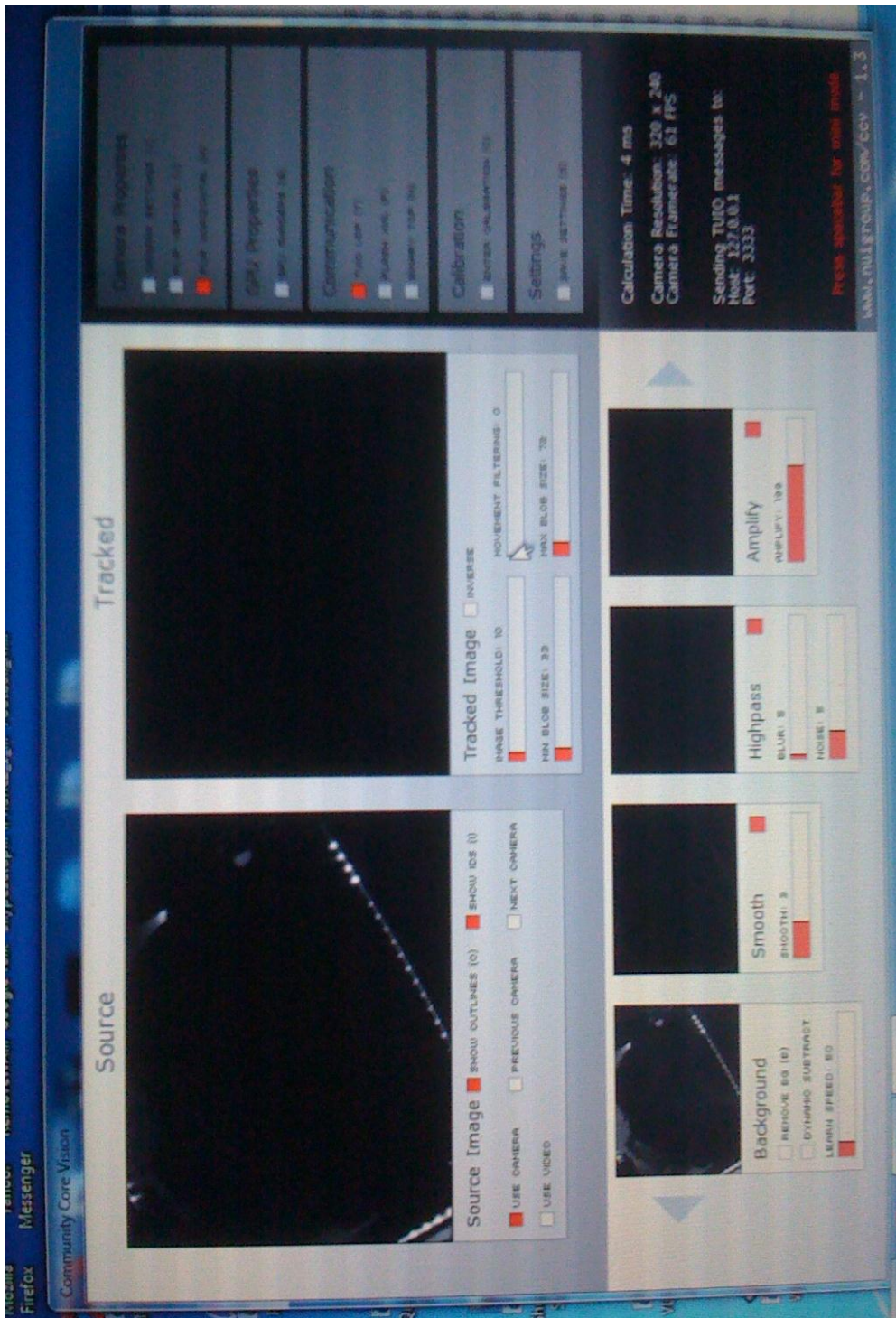


Figure 47 Without input



Figure 48 FTIR effect with inputs

From Figure 48, there are five fingers input which are well detected by the camera and one false or weak blob. There are several possibilities which lead to false blob :

- Different height of IR LED placement (precision)
- No reflective coil to prevent from IR light rays escape the touch surface
- Absent of compliant surface

Different height of IR LED placement issue arrive from the milling step. Where, the accuracy of milling is not 100% which lead to low precision of LED placement. Hence, there are several light rays escape from the touch surface. When there are obstacle, escaped light rays will be reflected and reflected light rays will be detected by the camera. Therefore, false blob is introduced. The workaround for the milling issue is, to calibrate the milling machine before proceed with the milling process. In this project, the machine was calibrated by the lab technician. However, the best setting for the milling is restricted by the limitation of the machine itself whereby the machine need to be service and several mechanical part need to be replace.

From the project, two IR LED aluminum frame has been tested instead of four. The result produced by two frame is not preferable because of the absent of reflective characteristic by other aluminum frame. Furthermore, the second objective of aluminum frame is to reflect the light rays inside the touch surface by preventing the light rays from escaping. Therefore, full reflection can be achieve. However, aluminum frame is not the optimal solution. Material with high reflective index such as shiny aluminum foil can reflect light rays better than aluminum frame.

Since there is no compliant surface used in this setup, frustrated light rays rate are quite low. The compliant surface which had been develop before, clear silicone, did not produce the desired output and therefore, the compliant surface is eliminate. The solution for the problem is to use clear silicon rubber sheet with

1mm thickness. Thinner rubber sheet is preferable because it able to frustrated more light rays compare to the thick silicon rubber sheet. Figure 49 shows the thin silicone rubber sheet.



Figure 49 Thin clear silicone rubber sheet [25]

4.2.1 Gesture Recognition

Gesture recognition is very important in multi-touch application where the developers can define specific action initiate by specific gesture. Gesture in modern application, is determined by how it will react with according to two different inputs (blob) and then translate the movement of the input to the action. The most popular gesture is “pinch and zoom” which is patented by Apple. However, there are several popular gestures as well such as rotate, translate and scale. Figure 50 show the gestures.

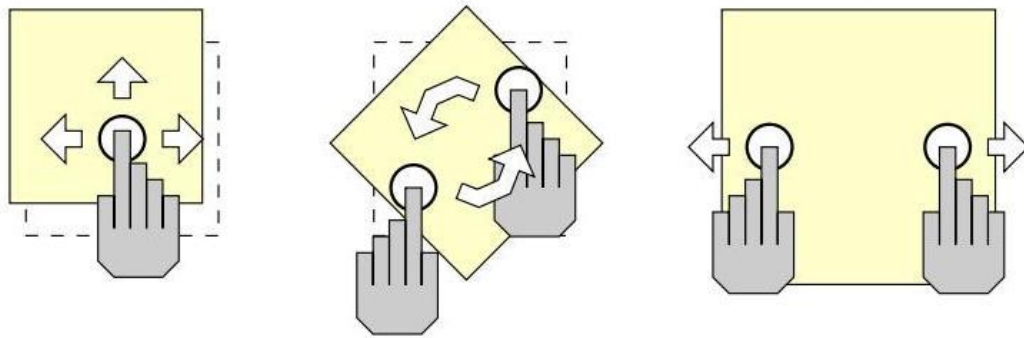


Figure 50 Translate, rotate and scale gestures

Those 3 gestures are the common gestures in today's multi-touch application. However, there are extensive of common gestures which are provided by Open Source Gesture Library. Figures 51 shows the gesture provided by Open Source Gesture Library. With the free licence to distribute, the developer can take the advantages of Gesture Library and work on new application.

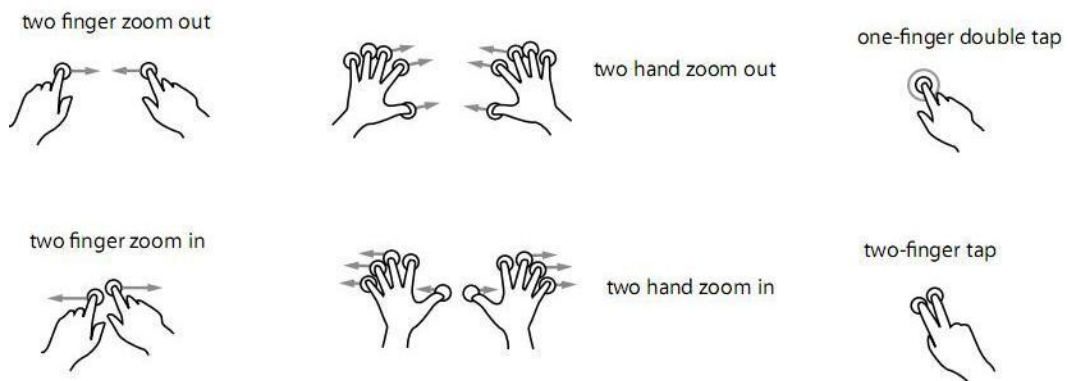


Figure 51 Open Source Gesture Library [26]

4.2.2 Overall Construction

Figure 52 shows the projected surface and Figure 53 shows the overall construction of the multi-touch which is currently developed. The table is quite high because of projection issue. Since normal throw projection is use in this

project, to achieve bigger image, the projector need to be outside of the table for the sake of simplicity. Mirror is use to reflect the projection. Without the mirror, the image size is restricted due to the projection or image throw by the projector. Therefore, short throw projector is preferable in order to build smaller multi-touch table with bigger image.

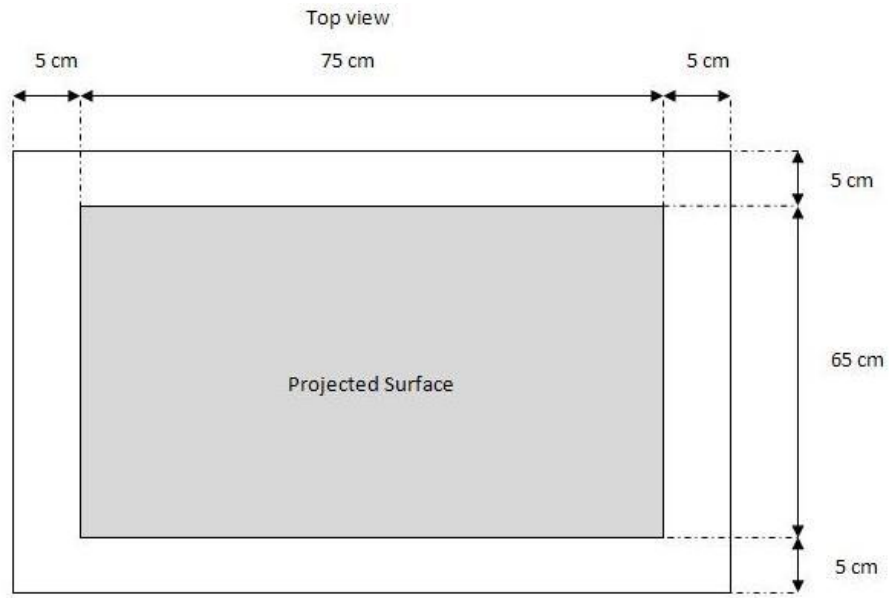


Figure 52 Top view

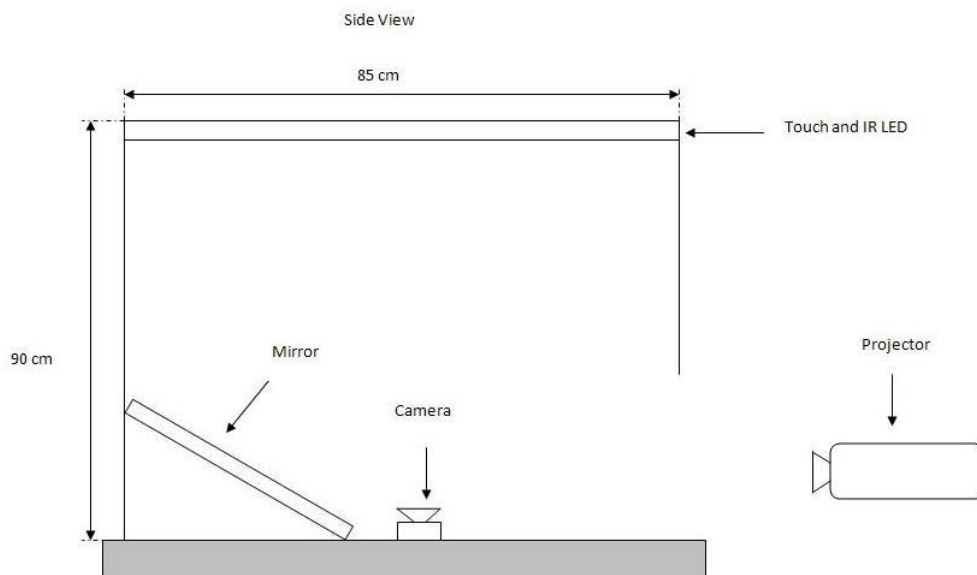


Figure 53 Side view

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Simulation work without the hardware setup thus lead to finished software before the implementation with the hardware setup. Before proceed with the simulation using the camera, simulation was done by using TUIO simulator. The purpose of TUIO simulator is to provide a platform for the simulation without devices. After that, simulation using the camera was done. From the result, the smoke application produces the output when the blob tracked by the camera. The high rates of fps from the camera also help the smoothness of the application itself. With the high rate of FPS, the camera able to take more images per second thus lead to desirable output.

From the early phase of table assembly, two IR LED frame is used in order to check the minimum requirement of IR LED which able produce desired frustrated IR. However, it did not produce much frustrated IR after being tested because of less IR trapped inside the acrylic. Therefore, four IR LED frame is used. From the result, it clearly shows that it able to trap more light thus produced better output.

Throughout the assembly phase, several changes have been made from the original plan because of the availability of the resources in order to build the table. One of the changes is in table design where bigger table will be build. Bigger projection surfaces can be built if short throw project is used.

5.2 Recommendation

From the previous result, multi-touch table can be enhanced with the right hardware setup. Thin silicon rubber sheet, reflective coil and last but not least, short throw projector. Short throw projector is preferable in order to simplify the design without using mirror thus lead to smaller multi-touch table. With the combination of compliant surface, short throw projector, and better table design, multi-touch have the potential to be in the market. Further development on software also can be developed. Interfacing multi-touch table with 3rd party application such as Microsoft Power Point will enhance the user experience with the particular software.

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APPENDICES

APPENDIX A

IR LED SPECIFICATION

GaAIAs Infrared Emitters (880 nm)

SFH 484
SFH 485



SFH 484



SFH 485

Wesentliche Merkmale

- GaAIAs-LED mit sehr hohem Wirkungsgrad
- Hohe Zuverlässigkeit
- Gute spektrale Anpassung an Si-Fotoempfänger
- Gegurtet lieferbar (im Ammo-Pack)
- Gruppiert lieferbar
- SFH 484: Gehäusegleich mit LD 274
- SFH 485: Gehäusegleich mit SFH 300, SFH 203

Anwendungen

- IR-Fernsteuerung von Fernseh- und Rundfunkgeräten, Videorecordern, Lichtdimmern
- Gerätefernsteuerungen für Gleich- und Wechsellichtbetrieb
- Rauchmelder (UL-Freigabe)
- Sensorik
- Diskrete Lichtschranken

Features

- Very highly efficient GaAIAs-LED
- High reliability
- Spectral match with silicon photodetectors
- Available on tape and reel (in Ammo-pack)
- Available in bins
- SFH 484: Same package as LD 274
- SFH 485: Same package as SFH 300, SFH 203

Applications

- IR remote control of hi-fi and TV-sets, video tape recorders, dimmers
- Remote control for steady and varying intensity
- Smoke detectors (UL-approval)
- Sensor technology
- Discrete interrupters

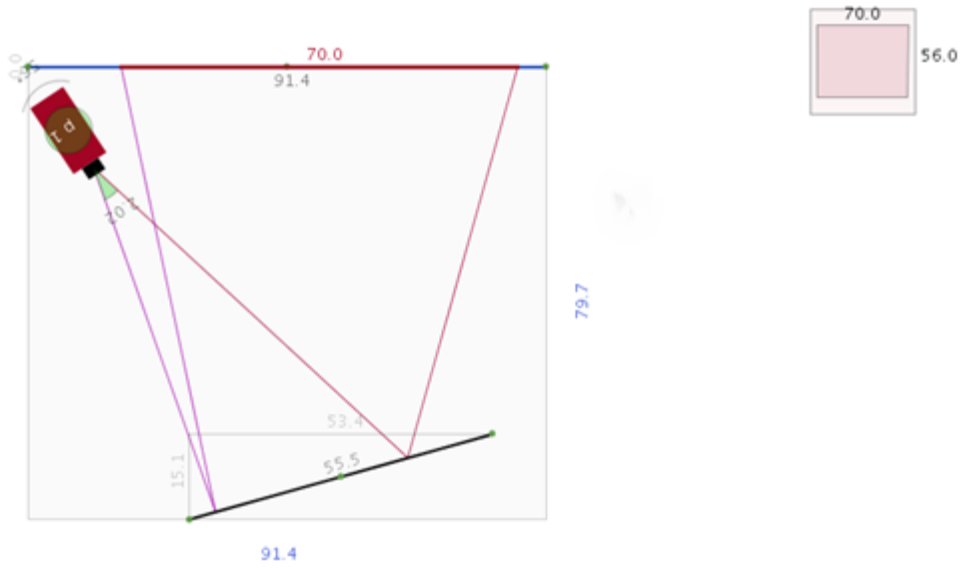
APPENDIX B
SONY PS3 EYE DISSAMBLE



APPENDIX C

ALTERNATIVE DESIGN 1

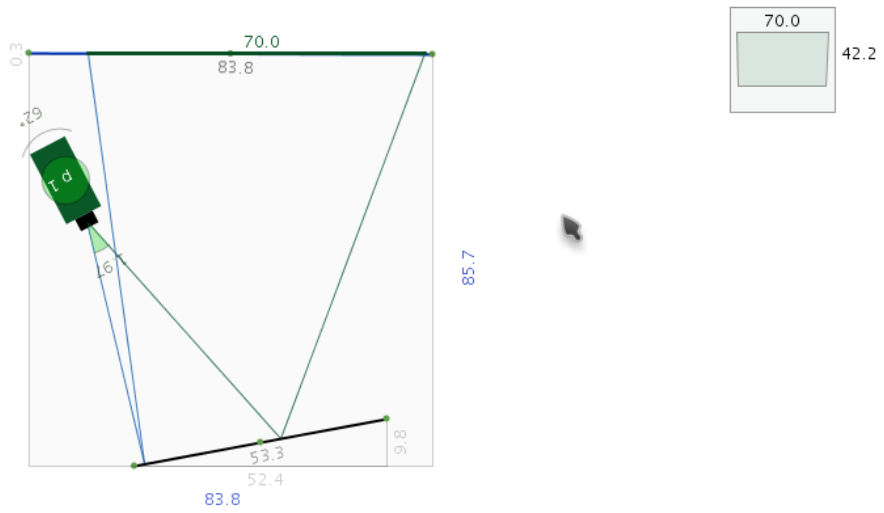
121.03	PROJ X	255	PROJ ALPHA	MIRRORS DIR	PROJ INFOS	1	MIRRORS
262.79	PROJ Y	2.01	THROW RATIO	MIRRORS ANGLES	BOUNDING BOX	1	PROJECTORS
60.00	PROJ WIDTH			MIRRORS HANDLES	ADVANCED BBOX	10	REFLECTIONS PER
30.00	PROJ HEIGHT	0.23	DISTANCE FACTOR	CHANGE COLORS			
56.49	PROJ ROTATION	1.00	DIMENSIONS PRECISION			16/9	16/10
0.00	PROJ OFFSET					4/3	CUSTOM
						1.60	CUSTOM RATIO
							SHOW HEIGHT (SIDE VIEW)
			70.00	TARGET WIDTH			



APPENDIX D

ALTERNATIVE DESIGN 2

181.25	PROJ X	255	PROJ ALPHA	MIRRORS DIM	PROJ INFOS	1	MIRRORS
302.28	PROJ Y	1.97	THROW RATIO	MIRRORS ANGLES	BOUNDING BOX	1	PROJECTORS
60.00	PROJ WIDTH	0.27	DISTANCE FACTOR	MIRRORS HANDLES	ADVANCED BBOX	10	REFLECTIONS MAR
30.00	PROJ HEIGHT	1.00	DIMENSIONS PRECISION	CHANGE COLORS		16/9	16/10
62.40	PROJ ROTATION	70.00	TARGET WIDTH			4/3	CUSTOM
0.00	PROJ OFFSET					1.60	CUSTOM RATIO
		LOCK PROJECTION TO					
						SHOW HEIGHT (SIDE VIEW)	



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APPENDIX E
GANTT CHART

WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ACTIVITY																				
Table design								M								S	F	F	F	
Wiring IR LED & hardware modification								D								T	I	I	I	
Submission of Progress Report 1								S								U	N	N	N	
Develop compliant and project surface								M								D	A	A	A	
Final table assembly																Y	L	L	L	
Submission of Progress Report 2								B												
Submission of Draft Report								R								W	E	E	E	
Submission of Final Report								E								E	X	X	X	
Submission of Technical Report								A								E	A	A	A	
Oral presentation								K								K	M	M	M	